

In this area, a sequence of Tertiary (ca. 32 Ma) plutons intruded into dolomitic sequences (Hauptdolomite, Thurwieser member) of the Ortler nappe, which led to a massive skarn formation as well as to high-grade dolomite marble formation. The mineral assemblage of the granodiorite is: amphibole + plagioclase + diopside + Fe-oxides + quartz ± K-feldspar ± titanite. The contact metamorphic marbles contain the peak metamorphic mineral assemblage forsterite + spinel + calcite.

Within the aureole a mineralogical zonation occurs. Adjacent to the granodiorite, garnet, rich in the grossular-andradite component, vesuvianite, epidote-clinzoisite, Fe-Ti- phases and diopside-fassaite-bearing clinopyroxenes occur, in the contact metamorphic marbles monticellite, clintonite, epidote-zoisite, forsterite, and spinel occur.

With respect to their stability with mixed fluids, monticellite, clintonite, and vesuvianite are good mineralogical indicators for low  $X_{CO_2}$  conditions. The late magmatic, high fluid activity led to a massive alteration of the skarn. Alteration products are prehnite, pumpellyite, members of the chlorite- and serpentinite-group, clintonite and hydrograndite. The observed coexistence of prehnite and pumpellyite defines *P-T* conditions of 200-270 °C and 0.2-0.3 GPa for this stage of the alteration. As an alteration product of spinel the layered double hydroxide mineral manasseite could be detected.

Calculated *P-T* conditions of the granodioritic intrusive bodies, based upon the Al-in-hornblende barometer and the hornblende-plagioclase thermometer, yielded crystallization *P-T* conditions of 0.15-0.3 GPa at 720-830 °C. Peak-temperatures of the skarn formation of 700-915 °C, depending on the  $SiO_2$  activity, were calculated with the zirconium-in-titanite thermometer. The solubility of monticellite in coexisting forsterite in the contact metamorphic marble allows the calculation of a maximum temperature of 850 °C.

In order to provide additional constraints on the skarn formation and the observed mineralogical assemblages, experimental investigations were conducted in the hydrothermal apparatus at 0.1 and 0.3 GPa between 650-750 °C using natural dolomite marbles as starting materials in the presence of excess  $H_2O$ . Only the experiment at 750 °C and 0.1 GPa yielded a reaction zone between the granodiorite and the dolomite containing the sequence (from the granodiorite into the dolomite): Al-bearing diopside, olivine and calcite + periclase. In most of the experiments the growth of phlogopite was also observed.

**Problems with high-T geochronometry or how to decipher time scales in the formation of the lower continental crust of the Ivrea-Verbano zone (N Italy)**

KLÖTZLI, U. & GÜNES, Z.

Dep. of Lithospheric Research, University of Vienna,  
Althanstr. 14, 1090 Vienna, Austria

Timing the onset and relaxation of the thermal perturbation induced by mafic intrusions in the lower crust is a crucial

issue to understanding the evolution through time of continental magmatism. Our understanding of this mechanism of crustal growth however is unsatisfactory inasmuch as reliable age data providing tight time constraints on the duration of the under-plating processes are mostly missing. One of the major open questions for instance is, whether magma formation and emplacement is a discrete or a continuous event and at what time scale these processes work.

Magmatic under-plating processes can be studied in the Ivrea-Verbano Zone (IVZ) of the Southern Alps (N Italy) and some partial answers to the above questions may thus be derived from the geochronological study of the IVZ rocks.

A large number of in-situ U-Pb zircon ages from the IVZ provides the basis for an interpretability model. Two sorts of age patterns are distinguished on statistical and petrological grounds:

- A) Ages which can be interpreted in a „straight forward“ manner: Inter- and intra-sample age variability is unimodal and shows a good to perfect normal distribution probability. Overall errors are <3 % 2RSD and only governed by analytical statistics. Samples displaying such ages are mostly derived from the amphibolite facies part of the IVZ and from Proterozoic to Permian intrusives.
- B) Age patterns which are „complex“: Inter- and intra-sample age variability is multi-modal and show no simple distribution. Overall errors are larger than expected from analytical statistics alone. Samples displaying such ages are mostly derived from the granulite facies part of the IVZ often having experienced a prolonged magmatic and/or metamorphic evolution.

Examples for „straight forward“ ages (group A): In the Val Sessera and Val Sesia sections the upper Mafic Complex (MC) crystallized at 288±4 Ma in a short time. Magmatic formation ages of cumulitic pyroxene-gabbros and norites interlayered with the main lithologies of the MC at Campello Monti (Val Strona di Omegna) are 1600±34 Ma and 964±22 Ma, respectively. An alkaline dike crosscutting the pre-MC and the MC rocks at Campello Monti has a Triassic intrusion age of 229±4 Ma. Examples for „complex“ ages (group B): Ages between 295 and 285 Ma obtained from samples from lower levels of the MC supports the concept that at depth the mafic body remained as a partially molten crystal mush for a larger time lapse. In addition, the age data indicate that some thermal event, probably related to the Variscan orogeny, affected the country rocks of the MC around 330 to 305 Ma. A later high-T overprinting event and subsequent slow cooling of garnet-hornblende-gabbros is documented by distinct zircon rims and recrystallised domains with an age of ca. 273 Ma to 260 Ma.

The compilation and integration of available high-T geochronometry data from the IVZ thus shows that the geological significance and reliability of the obtained ages strongly depends on the thermal history of the rock under investigation. These thermal histories and possible implications for other mineral-whole rock geochronometers are discussed.